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Development of Experimental Systems for Material Sciences Under Microgravity

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Abstract

Three experimental systems --G452, G453, G454-- have been developed for material science studies under microgravity by the NEC Corporation, as part of the Space Experiment Program of the Society of Japanese Aerospace Companies. These systems are to be flown as Get-Away Special payload for studying the feasibility of producing new materials.

The three systems all comprise standard subsystems consisting of : -

- Power supply
- Sequence controller
- Temperature controller
- Recorder (data recorder of VCR)
- Video camera,

together with the experimental modules carrying the hardware specific to the experiment.

1. Introduction

The Get-Away Special (GAS) Program has been offered by NASA to a number of countries including Japan, providing the opportunity to purchase payload space onboard shuttle flights. Japan has already had two experiments flown : -

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- G-005 for producing artifical snow[1], and
- G-032 for an experiment on the collision between small balls of metal and of water[2].

These payloads were developed by NEC under contract with the Asahi Shimbun and the Asahi Broadcasting Company. The Society of Japanese Aerospace Companies and NEC have utilized the experience gained in the development and manufacture of the foregoing two systems to further develop system for studying the feasibility of producing new materials under conditions of microgravity.

The most difficult problems calling for solution in development were to install the maximum possible number experiment modules within the prescribed limitations of space mass, which called for devising a miniaturized furnace for sample melting with minimum power consumption, to reduce the required number of batteries.

2. Overview of Experimental Systems

The principal characteristics and features of the three experimental systems are as summarized in Table 1. The hardware presents the external appearance shown in Figure 1.

The payload support structure is cantilevered out from the Experiment Mounting Plate (EMP), and supported laterally by 4 stoppers arranged on the two sides opposite each other.

As presented schematically in Figure 2, each system consists of an experiment module carrying the hardware specific to the experiment and a standard subsystem --of composition common to all three systems-- comprising 5 electrical circuit units for : -

- Sequence Control (SCU)
- Temperature Control (TCU)
- Power Conditioning
- Alarm
- Interface,

together with auxiliary components convering : -

- Battery assembly
- Transistor power switch unit
- Recording unit.

The SCU controls the ON/OFF status of all the other units

(Recording, Temperature Control, Experiment Module, ...). While the standard subsystem is thus common in form to all three systems, their substance --mode of control-- varies with the experiments, and to accommodate the variants, a high degree of flexibility has been incorporated in the subsystem, with micro-CPU and its peripherals including ROM --schematized in Figure 3-- adapted to the particular experiments. This flexibility will permit accommodation of alterations in the experimental control scenario by simple replacement of the ROM, even at a fairly late phase of experimental system development.

The Standard Recording Unit stores data from the experiment module (material temperature, heater current and other experimental measurements) as well as from the housekeeping subsystem (ambient temperature, battery voltage, ...). In some runs, in-situ images of crystal growth and other physical phenomena require recording, in which case the data recorder is replaced by a CCD color video camera and video cassette recorder: The monitor signals --e.g. material sample temperature-- are recorded on the audio track of the video tape, and image data on the video track. The video camera presents the external aspect illustrated in Figure 4.

3. Experiment Modules

The 12 experiments listed in Table 2 have been selected by a board of Japanese authorities interested in material science and space technology. Some of the modules have been developed by the experimenters, and others by the present authors.

Representative examples of the experiment modules are shown in Figures 5 to 8. Figure 5 and 6 indicate the arrangement of the miniature furnace or ampoule and material samples devised to satisfy the prescribed limitations of space and mass. These furnaces are embedded in thermal insulator, in the manner shown in Figure 9.

4. Concluding Remarks

The three experimental systems described above have been tested in simulated launch and orbit conditions, and have proved to function as expected. Using these systems, experiments have been successfully conducted for acquiring basic data on ground.

The systems thus developed are destined to be flown on the Space Shuttle in the near future, at which time acquisition can be expected of useful material science data under micro-gravitational condition.

5. Acknowledgments

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TABLE 1 MAIN CHARACTERISTICS AND FEATURES OF EXPERIMENTAL SYSTEMS

	G-452	G-453	G-454
SIZE DIAMETER HEIGHT	50 cm 70 cm	50 cm 70 cm	50 cm 70 cm
WEIGHT	70 kg	80 kg	70 kg
OBSERVATION/ RECORDER	DATA RECORDER	CCD COLOR VIDEO CAMERA VCR	CCD COLOR VIDEO CAMERA VCR
CONTROL	MICRO-CPU, ROM	MICRO-CPU, ROM	MICRO-CPU, ROM
EXPERIMENTS	SEMICONDUCTOR(4)	SEMICONDUCTOR (2) SUPERCONDUCTOR(1) BOILING PHENOMENA (1)	SEMICONDUCTOR (2) SUPERCONDUCTOR(1) FERROMAGNETIC MATERIAL (1)

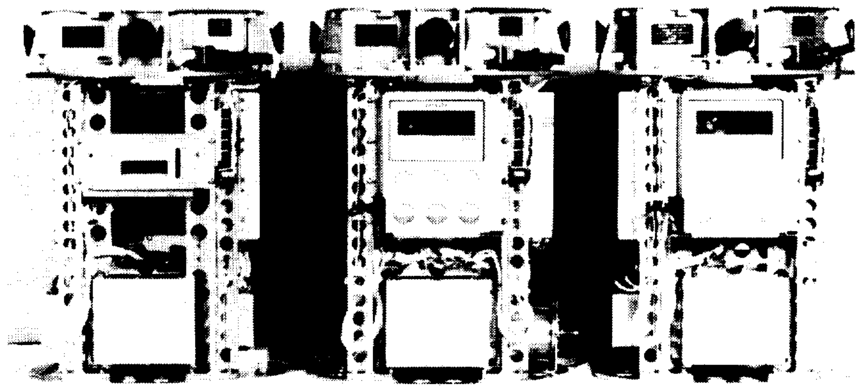

Figure 1 External view of three Experimental Systems

FIGURE 2

STANDARD BLOCK DIAGRAM OF EXPERIMENTAL SYSTEM

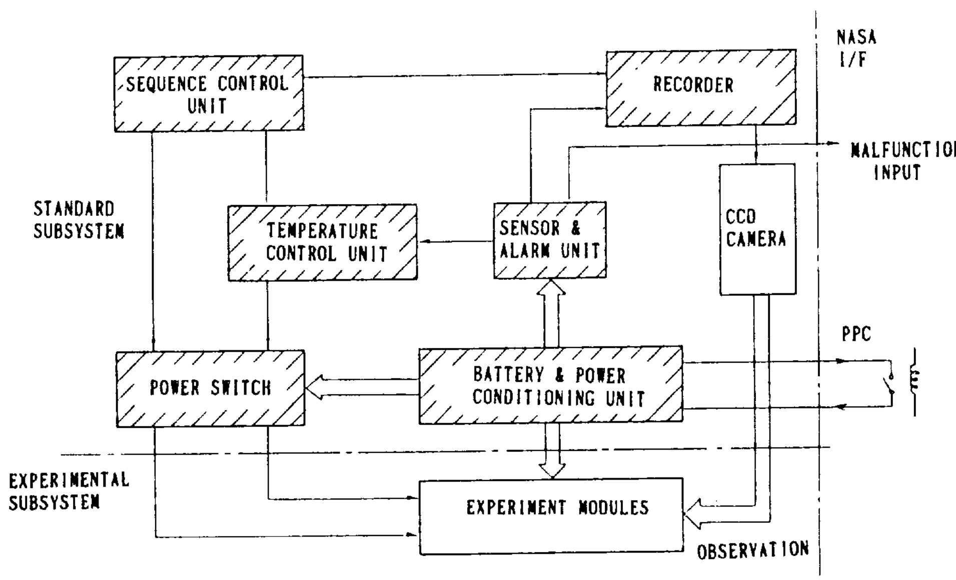

FIGURE 3

SCHEMATIC DIAGRAM OF CPU

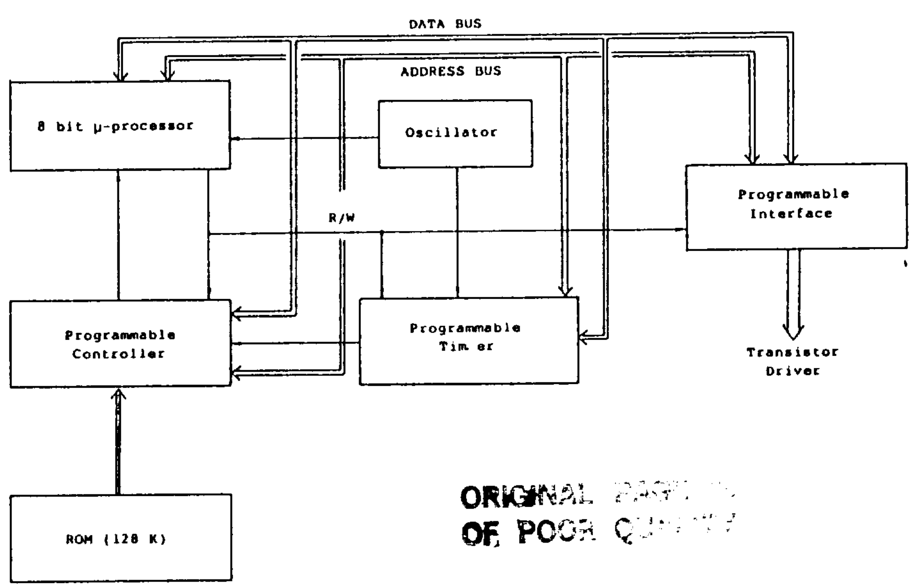

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FIGURE 4

EXTERNAL VIEW OF CCD CAMERA

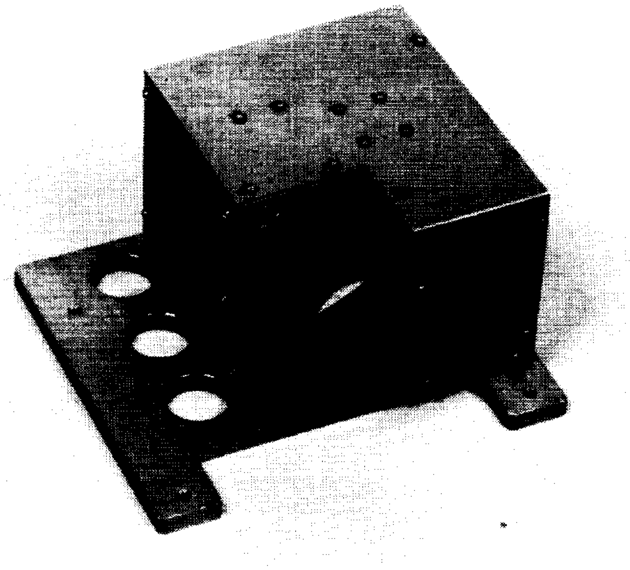

Table 2 Themes of 12 experiments for material sciences

System	No.	Experiment	Theme
G452	1	Semiconductor	Single crystal growth of GaAs from liquid phase (900 c)
	2	Semiconductor	Crystal growth of GaAs based mixed crystal (GaAsSb) (900 c)
	3	Semiconductor	Addition of a heavy element (Bi) to GaAs crystal (900 c)
	4	Semiconductor	Addition of a heavy element (Bi) to InSb crystal (650 c)
G453	6	Semiconductor	Formation of heterogeneous-alloy system from GaAs and Ge (900 c)
	7	semiconductor	Formation of thin-film-type single crystal of compound semiconductor (InSb)
	9	Superconductor	Formation of Si-Pb Alloy (immiscible on the ground) (1450 c)
	12	Boiling	Observation of the bubble form when an organic solvents is boiling under -g. (40 c)
G454	5	Semiconductor	Crystal Growth of In GaAs from vapor phase (800 c)
	8	Superconductor	Crystal growth of NbSe3 from vapor phase (800 c)
	10	Optoelectronic crystal	Crystal growth of an optoelectronic crystal (KH2PO4) by diffusion method (900 c)
	11	Superferromagnetic alloy	Formation of superferromagnetic alloy (Nd-Fe-B) (1400 c)

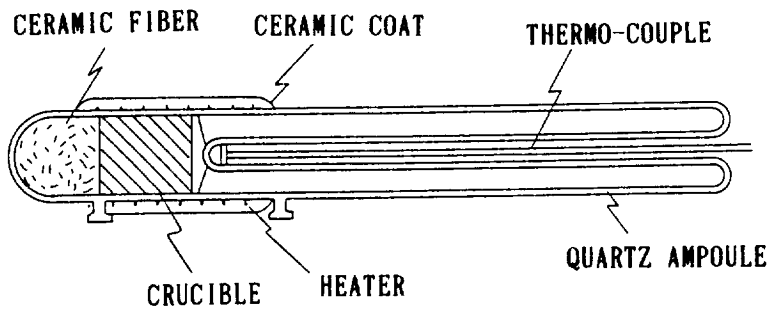

FIGURE 5 SMALL ELECTRIC FURNACES FOR EXPERIMENTS : Nos. 1,2,3.,9,11

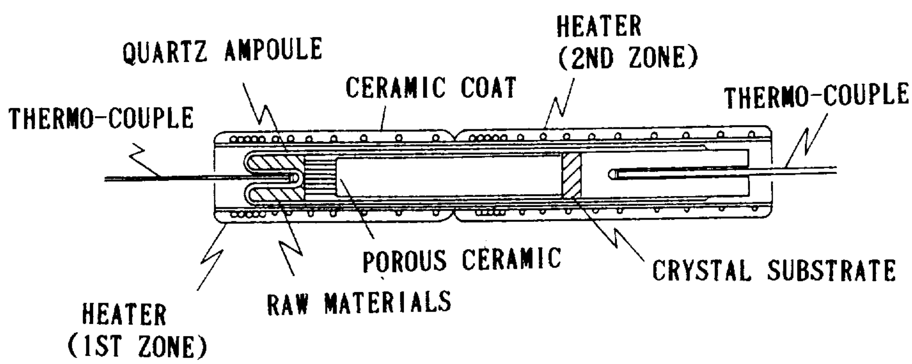

FIGURE 6 SMALL TEMPERATURE GRADIENT FURNACE
FOR EXPERIMENTS : Nos.5 AND 10

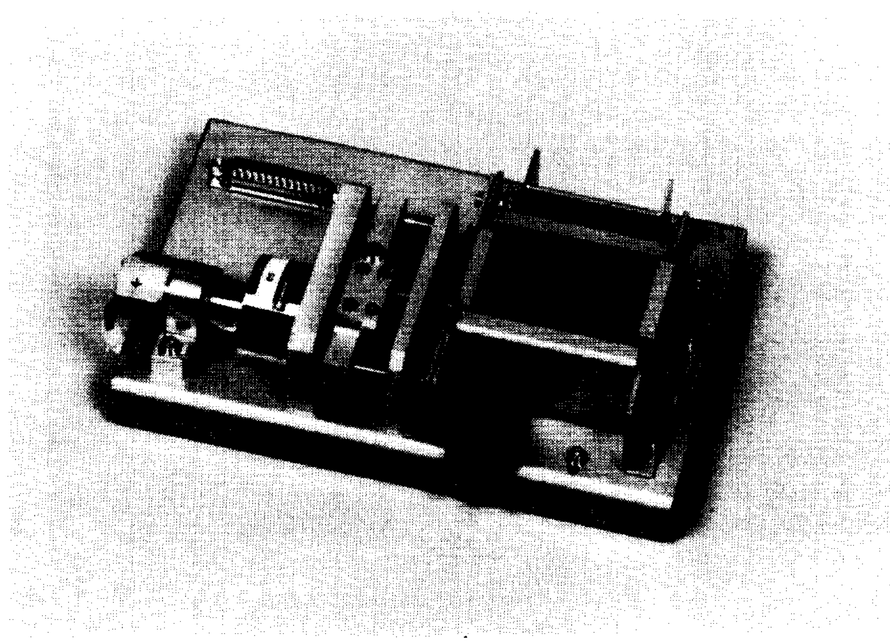

FIGURE 7 EXTERNAL VIEW OF EXPERIMENT No. 8 MODULE

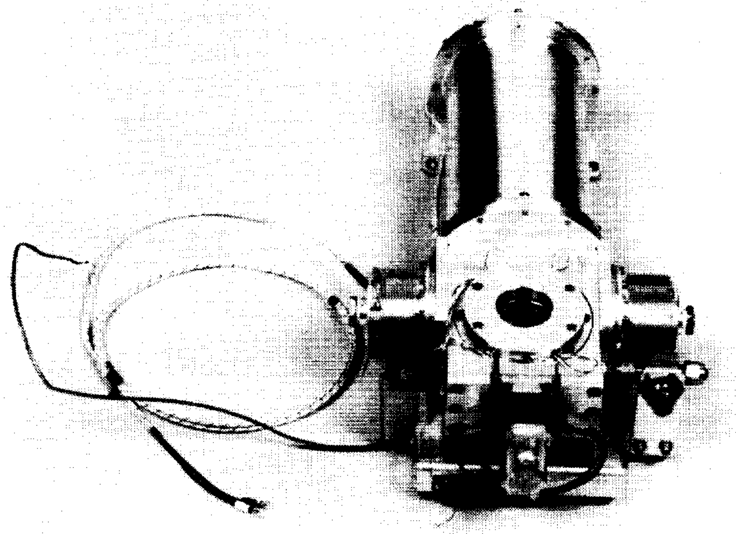

FIGURE 8 EXTERNAL VIEW OF EXPERIMENT No. 12 MODULE

FIGURE 9 SMALL FURNACES EMBEDDED IN THERMAL INSULATOR